ANALYSIS OF RESPIRABLE COAL DUST MONITORING PROGRAMS IN AUSTRALIA

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1.0 Abstract

Coal production in Australia is dominated by mining in the states of New South Wales and Queensland. In both these states, there is a significant proportion of coal produced from underground mines. While the incidence of Coal Workers pneumoconiosis and other respiratory disorders is very low, there is some concern in relation to the potential for an increase in respiratory disorders related to increasing levels of dust exposure from the use of longwall mining technology. The introduction of methane drainage has further increased dust generation.

The respirable dust data currently being collected has been analysed to assess its suitability for use in long term dose-response studies. Issues being examined include the correlation between dust and production levels, variability and sample size to provide adequate cumulative exposures over various time periods. The study has identified numerous confounding issues that have to be managed if a technically rigorous dose–effect relationship is to be established.

The development of health surveillance programs that examine respiratory function is providing information on subtle changes in respiratory function. In the future this may lead to evidenced based respiratory criteria for removing persons who work in high dust environments before significant impairment develops. Over a longer period, these databases will facilitate a widening of health outcome criteria to include pre-mature death and dust related disorders

2.0 Introduction

In 2000-01, Queensland's coal industry produced some 134.562 million tonnes of coal from surface mines and 38.321 million tonnes from underground mines (Department of Natural Resources and Mines, 2001). In the same year, New South Wales produced 85.149 million tonnes from surface mines and 53.554 million tonnes from underground mines. The majority of underground coal mines use the longwall method for the majority of production . There are currently some 34 longwall units operating. The top ten longwall mines produce between 3.4 and 5.6 million tonnes per year (Joint Coal Board, 2001a).

The mine operators and statutorary authorities undertake monitoring for respirable dust. In New South Wales, the Joint Coal Board (Cram and Glover, 1997) attempts to sample each longwall production shift every 6 months as well as regular sampling in other areas.. In Queensland, the Department of Natural Resources and Mines, undertakes quarterly dust testing. In addition to dust testing the Joint Coal Board and the Queensland Department of Mines and Energy also undertake health monitoring programs of coal mine worker at frequencies of 3 and five years respectively.

In the more productive longwall mines, respirable dust sampling has demonstrated that approximately 6.9% of personal monitoring samples taken in New South Wales exceed the 3.0 mg/m^3 statutory limit (Kuzil and Donoghue, 2001). Despite these elevated dust levels the incidence of coal workers' pneumoconiosis is negligible (Joint Coal Board, 2001 and Ham, 2000).

Between 1999 and 2000, the Joint Coal Board (2001a) reported on average 6.2 cases of compensatiable claims for respiratory disorders per year from a workforce of about 10,000 persons. This was only 2.2% of occupational disease claims. In Queensland, there are only a few compensatiable cases per year from a similar workforce. In 2000, the cost of these was less than

$2000 (WorkCover Queensland personal communication). These cover all types of respiratory complaints and are not generally pneumoconiosis.

An analysis of the Queensland the X-ray screening program for mine workers (Ham, 2000) identified 15 cases of pneumoconiosis between 1993 and 1999. Further investigation showed that most of the cases were contracted from outside the coal industry. Of those contracted while working in the coal industry, all were smokers and none had a long history of exposure to high levels of respirable dust in underground coal mines.

3.0 Background

Grantham (2001) discusses various criteria for determining sampling frequency related to hazardous exposures. Three issues that need to be considered are:

- how precise results need to be.
- what is the spread of exposures and
- how close is the exposure to accepted exposure standard.

The methods suggested include rule of thumb, using estimates of mean and standard deviation and finally compliance monitoring using power calculations. According to the rule of thumb, at lease 1 in 10 of any cohort should be sampled.

In the second method, using the estimates of mean and standard deviation,

$$\text{Number of samples} = (t_{value}.CV/E)^2$$

Where t_{value} is read from the t-statistics for degrees of freedom,
CV is coefficient of variation+ rough standard deviation divided by the rough mean and
E = error you are prepared to accept (ie. 10% or 20%.)

In the third method, power calculations are used to consider the variability associated with the geometric standard deviation and the level of error given nature of the problem This is the general approach used in the analysis of the data.

Pioneering work on the relation between coal dust exposure and subtle changes in respiratory function was undertaken by Soutar and Hurley (1986) who examined data collected in a series of British coal miner respiratory surveys between 1953 and 1980. Exposure was estimated by multiplying the hours worked in each broad occupational category by the estimated dust concentration to define exposure in terms of gram hours per cubic metre of sampled air. The study included over 4000 workers who were stratified by age and smoking status. The youngest age group was less than 50 years while the oldest was 75 to 80 years. Their study showed an effect on lung function as measured by the forced expired volume in one second (FEV_1) and forced vital capacity (FVC). The study showed that in non-smoking miners lung volume was reduced by 0.90 ml FEV_1/gram hours/m^3. This work and various subsequent UK studies were reviewed by Harrington (1996) who concluded that a loss to 1 litre FEV_1 and an exposure history of 20 years or more is a coal related compensatiable disorder under the social security arrangements.

It should be noted that this and most subsequent studies have relied on the measurement of respirable dust which penetrates down to the inner most parts of the lung and is considered to be the prime cause of the debilitating coal workers pneumoconiosis. The measure of FEV_1 is more a measure of respiratory tract restriction than overall volume.

The application of US dust compliance data in epidemiological studies has been explored by Seixas et al (1991). Unlike previous studies, their analysis showed a non-linear response between coal dust exposure and changes in respiratory function. The response to dust exposure was found to be considerable higher that in previous UK studies.

These marked differences suggest that there may be some additional confounding variables that are masking consistent estimation of the dose-response characteristics. Issues may include measurement errors, the use of respiratory protection, ambient levels of pollution and under-reporting of true dust exposures.

De Klerk and Musk (1998) reported an extensive study on mining related silicosis in Western Australia. This study identifies tobacco smoking as a significant contributing factor in the development of respiratory disorders in miners. This study extended from 1961 to 1997 in metalliferous mines.

Kuzil and Donoghue (2001) analysed respirable dust data collected by the Joint Coal Board between 1985 and 1999. Examining all longwall mining exposure data, they derived characteristic exposure values for each of seven occupational groups working in and around the longwall operation. The comparison of occupations did not take into account the variability between specific positions at individual mines. The study compared the differences between mines for all occupations. This indicated that the percentage of failures to comply with the $3mg/m^3$ statutory limit varied between 0% and 28.8%. Trends were also shown over time. This indicated that dust levels averaged across all mines have been fairly constant since 1991.

Bofinger and Cliff (1995) reported that in the longwall operations the 3 mg/m^3 air quality standard in the Coal Mining Regulations could not be guaranteed to be met at all Queensland mines. They reported on data that was routinely collected by the Dust Samplers of the Department of Mines and Energy. The current study analyses Queensland data collected from 1995 to 2000.

4.0 Methodology

The objective of this analysis was to :

- estimate the mean and variance of coal mine workers dust exposure,
- determine the frequency of sampling necessary for reliable exposure estimation using power calculations and
- consider confounding factors that may threaten the validity of future dose response studies.

The analysis considers respirable dust exposure for positions on a mine by mine basis, but only positions where there are more that 15 samples are considered for statistical analysis. Because different mines operate shift lengths varying from 8 to 12 hours, a factor of adjustment is used based on the report by Tiernan and Van Zanten (1998).

This analysis is examined in a risk management framework so that a higher reliability is required where a higher risk is identified. For the purpose of statistical analysis, a high risk group is defined as those exposed to greater that 50% of the maximum statutory level permitted ie $1.5mg/m^3$.

The study examines potential confounding factors. These include variation in production rates on sampling days and the effects of temporal variation in dust generation. A correlation between dust and production was found in several but not all mines. Adjustments were made for the differences between average production and production reported at the time of sampling.

5.0 Data Collection

The data analysed was collected by dust testing officers employed by the Queensland Department of Natural Resources and Mines (formerly the Department of Mines and energy) from 1995 to

2000. Personal samplers were calibrated before and after use. They were attached at the start of the shift and, when removed, the sampling time was noted. Shift production was noted. Samples were sent for analysis to the government testing laboratories at the Safety in Mines Testing and Research Station (SIMTARS). At SIMTARS, the samples are analysed for both coal and silica respirable dust. Other available data examined included the average quarterly shift production and shift length worked as reported in the Joint Coal Board Quarterly Longwall Reports.

Respirable dust sampling is undertaken using cyclone type Dupont 2500 personal dust samplers. These are attached to selected mine workers at the beginning of the shift and removed at the end of the shift. Sampling of mine workers focused on occupations where the risk of high dust exposures was considered the highest. The positions tested included longwall operators such as shearer drivers, chockmen and maingate operators as well as miners in development sections as shown in Table 1. Data collected at the time of sampling includes work position, length of shift and production.

Table 1: Dust and Silica failures and percentage failures

	Dust			Silica		
Position	No of Samples	No of Failures	% of Failures	No of Samples	No of Failures	% of Failures
Bolter	180	11	**6.1**	161	16	**9.9**
Cablehand	82	9	**11.0**	73	5	**6.8**
Chocks	205	31	**15.1**	199	33	**16.6**
Continuous miner	158	13	**8.2**	142	22	**15.5**
Maingate	54	6	**11.1**	48	5	**10.4**
Shearer	187	23	**12.3**	171	15	**8.8**
Shuttle Car	129	5	**3.9**	117	3	**2.6**
All positions	1,076	105	**9.8**	986	103	**10.4**

Table 2 shows the comparison between average longwall production as reported by the Joint Coal Board and the average production reported in the dust sampling records. The variation ranges from 41.3% to 161.4%.

Table 2: Comparison of average reported longwall production

Mine	Average Shift Production	Average Production at Sampling	% Difference
A	3467	2268	65.4
B	3719	4864	130.8
C	7630	6549	85.8
D	3490	3709	106.3
E	4757	5991	125.9
F	9752	4029	41.3
G	5100	3434	67.3
H	4275	6898	161.4
I	7728	4856	62.8
J	3505	3396	96.9
All Samples	5062	4516	89.2

6.0 Analysis of Data

Of the 12 underground mines in Queensland where the Department undertook quarterly respirable dust sampling, 10 mines had positions where there were more than 15 samples taken for these positions. This analysis focuses on the 24 positions that had more than 15 samples. The analysis includes both longwall operators and continuous miner section workers as shown in Table 3. From Table 3, there were:

- only two positions with less than $1 mg/m^3$,
- 7 positions between 1 and $1.5 mg/m^3$;
- 9 positions between 1.5 and $2 mg/m^3$ and
- 5 positions with over $2 mg/m^3$.

The highest two were a chock operator and a continuous miner operator both with $2.37 mg/m^3$.

Table 3: Analysis of Dust Exposure for Mine Workers

Mine	Position	Number	Mean	Median	Variance	Samples for variability	
						10%	20%
A	Shearer	21	1.79	1.50	1.442	475	119
B	Chocks	26	1.88	1.85	0.617	184	46
	Shearer	33	2.05	1.80	1.497	375	94
C	Bolter	22	1.02	0.85	0.287	288	72
	Cable	21	1.40	1.10	0.626	337	84
	Cont. Miner	29	1.59	1.20	2.215	916	229
	Shuttle Car	36	0.93	0.80	0.155	188	47
D	Bolter	15	0.78	0.80	0.046	79	20
	Chocks	15	2.15	1.90	1.334	302	76
	Cont Miner	17	1.33	0.90	0.536	320	80
	Shearer	18	1.44	1.50	0.280	141	35
E	Bolter	17	0.92	0.80	0.197	244	61
	Chocks	17	2.02	1.90	1.206	310	77
F	Chocks	17	2.38	2.20	1.697	315	79
G	Bolter	29	1.12	1.00	0.256	213	53
	Cable	16	1.64	1.55	0.413	161	40
	Cont Miner	19	2.37	1.70	2.352	440	110
	Shuttle Car	26	1.61	1.30	0.897	361	90
H	Bolter	22	1.35	0.85	1.512	877	219
	Chocks	41	1.94	1.70	1.478	412	103
	Shearer	34	1.70	1.60	0.977	354	88
I	Chocks	32	1.53	1.10	1.888	851	213
J	Chocks	18	1.50	1.30	0.837	391	98
	Shearer	20	1.56	1.15	1.380	599	150

A variance of dust and silica were obtained for each separate mining position. This was obtained in one of two ways. Firstly a stepwise regression was fitted for each position for dust and silica. Where explanatory variables were significant, they were kept and used in a regression model. The variance was then obtained from these models for each position. When the stepwise regression showed no significance, the numerical variance for the dust or silica in that particular position was obtained. These mines and positions are shown in Table 4. All other positions had their variances calculated by the standard variance formula.

Table 4: Analysis of Variance Dust Exposure vs. Production

MINE	POSITION	REGRESSION Sum of Squares	SIGNIFICANCE
B	Chocks	8.395	0.001
B	Shearers	10.106	0.014
D	Cont. Miners	7.112	0.002
E	Chocks	10.524	0.01
G	Cont Miners	24.592	0.005
J	Chocks	6.307	0.014

The equation used to calculate the sample size was:

$$n = \frac{(u+v)^2 \sigma^2}{(\mu - \mu_0)^2}$$

where:

n =	sample size
$\mu - \mu_0$ =	tolerance to be detected
σ^2 =	variance
ν =	power (90%)
u =	level of significance (5%)

A power value of 90% and a 5% level of significance of were used, as these values are the most widely used.

To obtain the sample size required, a tolerance level needed to be decided on and a variance needed to be calculated.

The tolerance level is a value used to detect a difference between an observed mean and the expected mean. For example, when using a tolerance of 10%, the size of the sample will allow for a detection of difference between the observed and expected mean of 10%. Therefore to detect a difference of 20%, less samples are needed, as this difference is larger and therefore easier to detect.

The two tolerance levels used were 10 and 20 per cent. A significance level of 5% and a power of 90% were selected, as these are the general values used. These tolerance levels were used on the mean value of dust levels for each position. For example an expected mean dust level of 2.0 and a tolerance level of 20% would give a $\mu - \mu_0$ value of 0.4 (2*0.2 = 0.4). Using the obtained sample size, observed means greater than 2.4 or less than 1.6 could be significantly different.

The values corresponding to the given variability represent the minimum number of samples that are required to detect that level of change. For example, to detect a 20 per cent variability in the dust for the shearers position in Mine A, 119 samples need to be taken.

7.0 Discussion

7.1 Comparison of Australian Exposure Data

Table 5 shows the Queensland and New South Wales data. It should be noted that the figures are not directly comparable as the New South Wales sampling is undertaken from crib-room to crib-room, while the Queensland data is collected from pit-top to pit-top except for sampling for long shifts. This sampling difference results in higher dust recorded in New South Wales for equivalent exposures.

While Queensland values are generally slightly higher than for their New South Wales counterparts, there is a marked difference in exposures for chock operators where the exposure in Queensland is 2.046 mg/m^3 compared to 1.61 mg/m^3 in New South Wales. It should be noted that commonly both production rates and shift lengths are higher in Queensland than in New South Wales. The relatively high exposures for maingate operators is important in that this area is considered as having lower (visible) dust and respiratory protection is not commonly worn.

Table 5:Comparison of Queensland and New South Wales Data

Position	**Queensland Data (1995-2000)**			**Joint Coal Board Data 1995-2000 (after Kuzil and Donoghue, 2001)**		
	Number	Mean	Std. Dev.	Number	Mean	Std. Dev.
Bolter / Driller	180	1.928	7.160	2	0.9	
Cable Hand	82	1.768	2.347			
Chockman	205	2.046	2.208	3143	1.61	1.1
Cont Miner	158	1.629	2.209			
Maingate	54	1.583	1.963	352	1.57	1.45
Shearer	187	1.926	1.201	2141	1.81	1.23
Shuttle Car	129	1.021	0.734			

Table 6 compares current Queensland dust exposure data to that from the 1995 study by Bofinger et al. At most mines, the mean dust levels have been reduced from the previous study. The exceptions are chock operators at Mine B and Mine F. Given both the high variance and the significant increases in productivity, these results should be interpreted with some caution.

Table 6: Comparison of Queensland Data 2000 and 1995

Mine	**Position**	**Monitoring Results 1995 to 2000**			**After Bofinger et al 1995**		
		Number	Mean	Variance	Number	Mean	Variance
B	Chocks	26	1.88	0.617	14	1.6	1.44
	Shearer	33	2.05	1.497	14	2.15	1.85
F	Chocks	17	2.38	1.697	9	1.8	1.16
I	Chocks	32	1.53	1.888	19	1.8	0.64
J	Chocks	18	1.50	0.837	25	2.3	0.81
	Shearer	20	1.56	1.380	25	2.85	2.61

7.2 Interpretation of Dust Data

For the purpose of statistical analysis, a high risk group is defined as those exposed to greater that 50% of the maximum statutory level permitted ie 1.5mg/m^3.

The analysis needs to consider the inherent confounding factors in the monitoring process. Mine workers usually wear respiratory protection in areas of obviously high dust, but remove this protection when visible dust reduces including crib rooms (for meals). Limited statistical data suggests that these areas have a reduced but still significant respirable dust. The effectiveness of the respiratory protection varies according factors such as type of device, face shape and facial hair. Without means of identifying these errors or controlling for them, the costs associated with high levels of accuracy in exposure assessment cannot be justified. On this basis, a sampling program that gives a 5% level of accuracy cannot be justified but a 10% level of accuracy seems reasonable.

In addition to the level of accuracy, the critical issue to examine in sampling frequency is the possible time frames for the onset of detectable respiratory change. Previous work by Ham (2000) showed that changed respiratory function on a population basis was not detectable at longwall operations which started in the late 1980s. This study did not specifically identify long wall workers. On this basis, it is concluded that a ten-year timeframe is appropriate.

Using the reliability of the estimate of the mean exposure (10%) and the time frame for statistically significant changes in respiratory function (10 years), and risk exposure, Table 7 can be used to determine the frequency of monitoring for various exposure levels in Queensland mines. This also gives an indication of the sampling frequency for other positions where reliable statistics are not yet available.

Table 7: Suggested Sampling Frequencies

Mine	Position	Mean	Variance	Samples for variability		Samples per year	
				10%	20%	High Risk	Low Risk
A	Shearer	1.79	1.442	475	119	48	
B	Chocks	1.88	0.617	184	46	19	
	Shearer	2.05	1.497	375	94	38	
C	Bolter	1.02	0.287	288	72		8
	Cable	1.40	0.626	337	84		9
	Cont. Miner	1.59	2.215	916	229	23	
	Shuttle Car	0.93	0.155	188	47		19
D	Bolter	0.78	0.046	79	20		2
	Chocks	2.15	1.334	302	76	31	
	Cont Miner	1.33	0.536	320	80		8
	Shearer	1.44	0.280	141	35		4
E	Bolter	0.92	0.197	244	61		7
	Chocks	2.02	1.206	310	77	32	
F	Chocks	2.38	1.697	315	79	32	
G	Bolter	1.12	0.256	213	53		6
	Cable	1.64	0.413	161	40	17	
	Cont Miner	2.37	2.352	440	110	50	
	Shuttle Car	1.61	0.897	361	90	37	
H	Bolter	1.35	1.512	877	219		22
	Chocks	1.94	1.478	412	103	42	
	Shearer	1.70	0.977	354	88	36	
I	Chocks	1.53	1.888	851	213	85	
J	Chocks	1.50	0.837	391	98	40	
	Shearer	1.56	1.380	599	150	60	

7.3 Future Research

This analysis has established a methodology to examine exposure data in fine detail. The next step is to consider the more complex issues associated with quantifying health outcomes. These health outcomes are key elements in dose-response studies. Some data is available on confounding factors such as age, smoking status and previous respiratory disease. There is also a body of literature on community norms. Other factors such as differences in geology, types and use of respiratory protection and work practices will have to be assessed in subsequent studies.

The most difficult challenge will be to target the population with a long history of dust exposure and to estimate their cumulative exposure and determine their medical outcomes. This is a starting point for exposure based health surveillance in which technically valid dose-response relationships are used to trigger administrative arrangements where persons at risk of long term dust related illness are removed from high risk exposure activities.

8.0 Conclusions

In Australia, bord and pillar mining using integrated mining and roof support is the dominant underground mine development method and is associated with very low levels of respirable dust. In the last few years, the cut and flit method used in the United Sates has been introduced in some mines resulting in increased dust levels.

Longwall mining was introduced in New South Wales in the early 1960s and in Queensland in 1986. This method is associated with high dust levels which occasionally exceed the 3mg/m^3 statutory limit.

While the incidence of coal workers pneumoconiosis is negligible, there is some evidence that longwall dust exposure is causing diminished respiratory function. Overseas court actions have established that coal dust related decrease in respiratory function may be a compensatiable disorder.

Statistical analysis of Queensland respirable dust data collected by the Department of Natural Resources and Mines from 1995 to 2000 has examined the mean and the variance for 24 high risk positions at 10 underground coal mines. Only positions where there were more than 15 samples were included in the study.

Analysis of variance has shown that in several positions there is a relation between production and dust make. Using production data, the 'production corrected' estimates of dust exposure are used to more accurately characterise coal workers dust exposure. At some mines there was a significant difference between the average production of the mine at that recorded at the time of sampling. This difference ranged from 41.3% to 161.4%

Where no correlation between dust and production was found, there were generally higher levels of respirable dust. This may be an indicator that the dust suppression and ventilation management at these mines may be of a lower standard that that at the mines where a relationship was identified.

The application of power calculations was used to estimate the sampling requirements to give a reliable estimate for exposure for use in subsequent dose response studies. It is presumed that a 10 year period should be considered when examining changes to respiratory function on a community basis. Where the risk is lower (less than 1.5mg/m3) at reliability of 20% was assumed compared a reliability of 10% for higher risk exposures. Using the power calculation, sampling for the most consistent longwall position should be undertaken 14 times per year compared to 85 times a year for the most variable position.

The wide variability shown in some mines is likely to be caused by a combination of small sample size, variable production rates, ventilation management and dust suppression effectiveness. By increasing the testing frequency, management attention to areas within their control could be increased.

While this study has examined a number of confounding factors, several issues need to be examined in future studies. The use of respiratory protection is a significant variable that is not well documented. Allied to this is the dust exposure of mine workers in parts of the mine where no respiratory protection is used because they are considered as dust free zones.

The studies to date focus on respirable dust. The loss in respiratory function being assessed is, in part, related to airway function. There is a possibility that the airway diseases may be partly affected by coarser fractions of dust than those currently being monitored. This may be important in the Australian context where high ventilation velocities are used for both cooling and the clearance of methane from the face areas.

Overseas studies have put the 3mg/m^3 coal dust standard in Australia into doubt as a guarantee that coal workers can have a career in the high dust positions without deleterious effect on their health. Current Australian studies cannot confirm that Australian coal workers are being harmed because the exposure to high dust levels is a relatively recent phenomenon.

Recent changes to coal mining legislation in Australia, has placed obligations on mine operators to develop technically sound approaches to risk management. This study provides a technically based approach that may be used to determine the frequency of testing exposures of respirable coal dust. The approach is risk based and considers the following factors;

- proximity of exposure level to community standards,
- variability of parameter assessed,
- established timeframes for detecting measurable change,
- standards of statistical confidence.

The outcome is a reliable long-term estimate of coal dust exposure. This is not an endpoint but rather a starting point for exposure based health surveillance in which technically valid dose-response relationships are used to trigger administrative arrangements where persons at risk of long term dust related illness are removed from high risk exposure activities.

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10.0 References

Attfield M. D. and Hearl F. J. 1996. Applicaation of data on compliance to epidemiological assessment of exposure-response: the case of data on exposure of United States coal miners, in Occupational Hygiene Vol.3 pp177-184, OPA Amsterdam..

Cram K. and Glover D. 1997. Studies on respirable coal dust in underground coal mines – New South Wales, Australia, in 27th International Conference of Safety in Mines Research Institutes, New Delhi India.

Bofinger C. M., Cliff D. I,. and Tiernan G. 1995. Dust and noise exposures of longwall workers in the Bowen Basin, Queensland Australia' in 26th International Conference of Safety in Mines Research Institutes, Central Mining Institute, Katowice Poland.

Department of Natural Resources and Mines 2001. Queensland Mining Industry Safety and Health Performance Report 2001.

Grantham D (in press). Occupational Health and Hygiene Guidebook for the WHSO

Ham B. W.(2000) The role of health surveillance Queensland coal mining industry, Masters Thesis (OHS) Queensland University of Technology, Brisbane.

Harrington J. M. 1996. Chronic Bronchitis and Emphysema [underground coal workers]– A report by the Industrial Injuries Advisory Council, Social Security Department, UK.

Joint Coal Board 1997. 50th Annual Report, Sydney Australia.

Joint Coal Board 2001. 53rd Annual Report, Sydney Australia.

Joint Coal Board 2001a Longwall Mines – Statistical Review 2000-01.

Joint Coal Board 2001b NSW Coal Industry Injury and Disease Claims 2000-01.

Kizil G. and Donoghue A. M. 2001. 'Coal Dust Exposures in the longwall mines in New South Wales: a respiratory health risk assessment using Joint Coal Board exposure data from 1985 to 1999', in Queensland Mining Industry Health and Safety Conference 2001, Queensland Mining Council and Department of Natural Resources and Mines, pp297-308.

Seixas N. S.,Moulton L. H., Robins T.G., Rice C.H., Attfield M. D., and Zeller E. T. 192. estimatioin of cumulative exposures for the National Study of Coal Workers Pneumoconiosis. Applied occupational environment and Hygeine, 6, 1032-1041.

Tiernan G. and Van Zanten D. 1998. Development of an extended shift exposure limit adjustment Factor for coal mine dust., a JCB Health and Safety Trust funded project, SIMTARS, Redbank, Queensland..